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TABLE OF CONTENTS

VOLUME 1

JAXA SS 1 – SPACE UTILIZATION SESSION #1 FOR SAFE AND AGRICULTURE

OVERVIEW OF SPACE APPLICATIONS FOR ENVIRONMENT (SAFE) INITIATIVE AND PROTOTYPES	1
<i>K. Hamamoto, N. Matsuura, Y. Kaneko, M. Koide, K. Oyoshi</i>	
ASIAN RICE CROP MONITORING FOR GEO-GLAM	2
<i>S. Sobue, K. Oyoshi, Y. Kaneko, K. Kobayashi, T. Nagano, T. Okumura, N. Tomiyama</i>	
RICE CROP MONITORING IN THE MEKONG DELTA, VIETNAM USING RADAR REMOTE SENSING DATA	3
<i>L.-D. Nguyen, L.-T. Thuy, H.-P. Phung, P.-T.-M. Thy</i>	
REMOTELY SENSED CROP MONITORING FOR AGRICULTURAL DEVELOPMENT PLANNING IN INDONESIA	4
<i>R. Shofiyati, D. Dirgahayu, H. Syahbuddin, D. Nursyamsi</i>	
AGROMETEOROLOGICAL OUTLOOK (JASMIN)	5
<i>K. Kobayashi, K. Oyoshi, S. Sobue, T. Okumura</i>	

JAXA SS 2 – SPACE UTILIZATION SESSION #2 FOR ALOS-1 AND QZSS (EO+GNSS)

REPORT OF ALOS-2 / PALSAR-2 LAUNCH AND ITS RECENT STATUS	6
<i>R. Natsuaki, M. Watanabe, T. Motooka, M. Ohki, M. Shimada</i>	
ASIA OCEANIA MULTI-GNSS DEMONSTRATION CAMPAIGN	7
<i>K. Hisano, H. Tateshita, K. Sato, Y. Wakabayashi, S. Kogure</i>	
PRECISION FARMING AT UNIVERSITY PUTRA MALAYSIA (UPM)	8
<i>A. Shariff, A. Rashid</i>	
PRECISION SPRAYING USING A RADIO-CONTROLLED QUAD-COPTER AND POSSIBLE USE OF GNSS	9
<i>P. Soni, K. Noosom</i>	

SESSION A1 – INDOOR/3D

A POINT-BASED RENDERING FOR 3D POLYGON EXTRACTION IN INDOOR ENVIRONMENT	10
<i>M. Nakagawa, T. Yamamoto, K. Kataoka, M. Shiozaki, T. Ohhashi</i>	
THE GENERALIZATION OF BIM/IFC MODEL FOR MULTI-SCALE 3D GIS/CITYGML MODELS	16
<i>S.-C. Yu, T.-A. Teo</i>	
3D RECONSTRUCTION BY COMBINING TERRESTRIAL LASER SCANNER DATA AND PHOTOGRAMMETRIC IMAGES	22
<i>L. Han, Y. Chong, Y. Li, D. Fritsch</i>	

SESSION A2 – AGRICULTURE & CROP

REVIEW OF VEGETATION INDICES FOR VEGETATION MONITORING	28
<i>R. Dutta</i>	
SPECIES DISTRIBUTION MODELING TO AID REMOTE SENSING OF THE STARCH-RICH SAGO PALM IN THE PHILIPPINES	34
<i>M. Santillan, J. Santillan</i>	
STUDY ON ESTIMATING RICE YIELD BY USING CHINESE SATELLITE IMAGES	39
<i>W. Li, Q. Wang</i>	
A COMPARISON OF VEGETATION SPECTRAL INDICES DERIVED FROM LANDSAT 8 AND PREVIOUS LANDSAT GENERATIONS	45
<i>T. Nguyen, X. Pham</i>	
RICE FIELD MONITORING USING INTRINSIC IMAGES DECOMPOSED FROM FIELD SERVER IMAGERY	51
<i>P. Srestasathien, N. Soontranon, P. Rakwatin</i>	

SESSION A3 - CLIMATE

EMPIRICAL ORTHOGONAL FUNCTION COMPUTATION AND ANALYSIS OF AEROSOL OPTICAL DEPTH FROM MODIS DATA OVER NORTHERN INDIA	57
<i>M. Singh, P. Venkatachalam</i>	
USING TERRAIN-RELATED VARIABLES TO ASSESS THE NEGATIVE EFFECTS OF TOPOGRAPHIC OBSTACLES ON TAIWAN RED CYPRESS DISTRIBUTION	63
<i>W.-K. Lai, Y.-H. Lin, N.-C. Lo, K.-Y. Huang</i>	
RELATIONSHIP BETWEEN PM2.5 CONCENTRATIONS AND METEOROLOGICAL DATA IN NAGASAKI	68
<i>J. Wang, S. Ogawa</i>	

USING OF GIS SOFTWARE FOR MAPPING THE CLIMATIC DATA OBTAINING BY INTERNET NETWORK	74
--	----

S. Ali

HYPERSPATIAL RESOLUTION OF GROUND BASED REMOTE SENSING FOR NATURAL LIMESTONE CHARACTERIZATION: A CRITICAL INPUT FOR ROCK SLOPE HAZARD ASSESSMENT IN THE TROPICS	90
--	----

K. Razak, R. Hasan, A. Aitin, L. Sheng, Z. Mohamed, Q. A'Zad, R. Bakar

SESSION A4 - FORESTRY

ASSESSMENT OF PEAT SWAMP FOREST COVER OF MALAYSIA USING REMOTE SENSING	96
---	----

M. Faidi, K. Hamzah, M. Mismam, S. Yaakub

ABOVEGROUND BIOMASS ASSESSMENT OF DEGRADED RAINFOREST USING IKONOS-2: SPECIFIC FOREST CLUSTER ANALYSIS	102
---	-----

A. Korom, M.-H. Phua, Y. Hirata, T. Matsuura, H. Saito, W. Wong

APPLICATIONS OF MULTITEMPORAL OPTICAL IMAGES FOR FOREST RESOURCES STUDY IN MONGOLIA	108
--	-----

D. Enkhjargal, D. Amarsaikhan, V. Battsengel, T. Bat-Erdene, J. Sod-Erdene, G. Tsogzol

USING THE NDVI DIFFERENCING FOR MAPPING OF DIPTEROCARP FOREST IN SAVANAKET PROVINCE, LAO PDR	112
---	-----

N. Nguyen, T. Le, V. Sengtianthr, X. Pham, V. Pham

TROPICAL FOREST CHANGE DETECTION BY A TREND ANALYSIS OF TIME SERIES SATELLITE IMAGES	119
---	-----

G. Takao, K. Hamzah, A. Faidi, H. Omar

SESSION B1 – DATA PROCESSING

FUSION OF OPTICAL AND SAR IMAGES FOR THE ENHANCEMENT OF URBAN FEATURES	125
---	-----

D. Amarsaikhan, C. Bolorchuluun, N. Ganchuluun, M. Ganzorig, B. Nergui, D. Enkhjargal

THE COMPARISON OF POLARIMETRIC SAR DATA FOR UNSUPERVISED CHANGE DETECTION USING KI ALGORITHM	131
---	-----

K. Chureesampan

UNCERTAINTY ESTIMATION OF IMAGE CLASSIFICATION IN HAZE-CONTAMINATED AREA THROUGH WEIGHTS OF EVIDENCE MODEL	137
---	-----

Y.-S. Shiu, M.-L. Lin, Y.-C. Kao, Y.-C. Chuang

EXPERIMENT OF THE HIGH ACCURACY POSITIONING BY QUASI-ZENITH SATELLITE MICHIBIKI OF JAPAN	144
---	-----

N. Sekiguchi, M. Shikada

THE IMPACT OF SPATIAL ARRANGEMENTS OF BUILT LAND COVER TYPES ON URBAN WARMING	150
--	-----

S. Myint, B. Zhang, F. Chao, M. Smith

SESSION B2 – AGRICULTURE & CROP

THE APPLICATION OF SATELLITE IMAGERY TO ESTIMATE AGRICULTURAL LOSSES IN TAIWAN	156
---	-----

R.-Y. Lee, C.-H. Hsu, T.-C. Lei, Y.-S. Shiu

RICE CROP PHENOLOGY USING TEXTURE ANALYSIS ON TIME-SERIES IMAGES OBTAINED FROM STILL CAMERA	162
--	-----

N. Soontranon, P. Srestasathien, P. Rakwatin

PHENOLOGY-BASED CLASSIFICATION OF MAJOR CROPS AREAS IN CENTRAL LUZON, PHILIPPINES FROM 2001-2013	168
---	-----

D. Torre, G. Perez

ON EXCHANGEABILITY OF SPECTRAL MEASUREMENTS OBTAINED FROM MULTI-PLATFORM SATELLITE SENSORS—CASE STUDY FOR MONGOLIAN STEPPE	174
---	-----

A. Hirano, B. Batbileg

CHANGE DETECTION OF HYDROLOGIC NETWORKS USING LANDSAT IMAGERIES FROM 1972 TO 2013 IN MEKONG DELTA	180
--	-----

Z. Liu, Y. Ma, N. Wang

SESSION B3 - CLIMATE

CLIMATE CHANGE IMPACT AND VULNERABILITY ASSESSMENT OF FORESTS IN THE INDIAN WESTERN HIMALAYAN REGION: A REMOTE SENSING & GIS BASED STUDY OF HIMACHAL PRADESH, INDIA	186
--	-----

S. Upgupta, J. Sharma, N. Ravindranath

EVALUATION OF MODIS CLOUD PRODUCT-DERIVED RAINFALL ESTIMATES	192
---	-----

J. Punay, G. Perez

VALIDATION OF A SIMPLIFIED AEROSOL RETRIEVAL ALGORITHM (SARA) OVER BEIJING	197
<i>J. Nichol, M. Bilal</i>	
VEGETATION COVER AS AN INDICATOR FOR EFFECTIVE IMPLEMENTATION OF LAND USE REGULATIONS AND LAND DEGRADATION RISK: A CASE STUDY IN SARDINIA	203
<i>V. Spanu, D. Shrestha</i>	
ANALYSIS OF AEROSOL OPTICAL DEPTH AND ANGSTROM EXPONENT NUMBER OVER SINGAPORE 2007 – 2014	204
<i>A. Muller, S. Salinas, B. Chew, T. Li, S. Liew</i>	

SESSION B4 - FORESTRY

WOULD ILLEGAL LOGGING BE PREDICTED ACCURATELY AND PREVENTED BEFOREHAND BY USING REMOTE SENSING AND GIS?	210
<i>T.-A. Lin, S.-H. Tseng, N.-C. Lo, K.-Y. Huang</i>	
MAPPING RUBBER TREE GROWTH BY SPECTRAL ANGLE MAPPER SPECTRAL-BASED AND PIXEL- BASED CLASSIFICATION USING SPOT-5 IMAGE	215
<i>H. Dibs, S. Mansor</i>	
DETECTION AND CALCULATION OF PEATLAND SUBSIDENCE IN INDONESIA BY USING INTERFEROMETRIC SYNTHETIC APERTURE RADAR	221
<i>S. Tsunoda, W. Takeuchi</i>	
EXPLOITING THE DMC SATELLITE CONSTELLATION FOR APPLICATIONS IN AGRICULTURE, FOREST MONITORING AND DISASTER RESPONSE	227
<i>D. Hodgson, G. Holmes, E. Lobo, Y. Pingping, M. Sweeting</i>	
EXPERIENCES WITH LIDAR CANOPY PENETRATION IN A DENSE TROPICAL RAINFOREST	228
<i>M. Isenburg, H. Trunzer, F. Malmer</i>	

SESSION C1 – DATA PROCESSING

A NOVEL GCP MATCHING MODEL FOR IMAGE GEOMETRIC CORRECTION BY BIOLOGICAL SEQUENCE ALGORITHMS	234
<i>T.-C. Lei, Y.-M. Huang, G.-S. Tzeng, Y.-S. Shiu</i>	
A ROBUST MATCHING METHOD FOR REMOTE SENSING IMAGES OF DIFFERENT VIEWPOINT ANGLES BASED ON REGIONAL COHERENCY	241
<i>Z. Shao</i>	
TEXTURE MAPPING FOR BUILDING FACADES USING TERRESTRIAL LIDAR POINT CLOUDS AND CLOSE RANGE IMAGES	250
<i>L.-L. Chan, L.-C. Chen</i>	
OBJECT-BASED DENSE MATCHING WITH FEATURE CONSTRAINTS FOR DSM GENERATION	253
<i>W.-C. Chang, L.-C. Chen</i>	
MULTINOMIAL LOGISTICS REGRESSION FOR DIGITAL IMAGE CLASSIFICATION	256
<i>M. Myint</i>	

SESSION C2 – DECISION SUPPORT & MODELS

MONITORING AND PREDICTING THE URBAN DEVELOPMENT OF GUATEMALA CITY, GUATEMALA	263
<i>A. Tercero, C.-F. Chen, S.-H. Chiang</i>	
PROBABILISTIC URBAN SIMULATION IN HO CHI MINH CITY, VIETNAM	269
<i>S.-H. Chiang, N.-T. Son, C.-F. Chen</i>	
DEVELOPING GIS DECISION SUPPORT TO STAKEHOLDERS ON AGRICULTURAL LAND USE PLANNING IN HA TINH PROVINCE, VIETNAM	275
<i>M. Huy, B. Thanh</i>	
STUDY OF LANDSCAPE INDICES ANALYSIS IN ESTABLISHMENT PRINCIPLES OF ADMINISTRATIVE ZONES IN TAIWAN	280
<i>Y.-C. Chuang, Y.-C. Kao, R.-Y. Lee</i>	
ECONOMICS DEVELOPMENT OF MERAUKE DISTRICT BASED ON TOPONYMY ASPECT	288
<i>H. Helman</i>	

SESSION C3 – GIS MODELS

ROBUSTNESS AND ACCURACY ASSESSMENT OF INVISIBLE WATERMARKING OVER GEOSPATIAL VECTOR DATA	294
<i>S. Zope-Chaudhari, P. Venkatachalam, K. Buddhiraju</i>	
A STUDY ON THE METHODOLOGY OF A GIS-BASED IMPERVIOUS SURFACE MAP PRODUCTION FOR URBAN AREAS	300
<i>S. Oh, K. Kim, C. Lee</i>	
THE ROLE OF GIS AND RS FOR PASTURELAND STUDY IN NORTHERN MONGOLIA	307
<i>D. Amarsaikhan, M. Saandar, B. Byambadolgor, E. Jargaldalai, D. Enkhjargal</i>	

GIS FRAMEWORK FOR PLAGUE RISK ASSESSMENT	311
<i>J. Zhao, Q. Li, D. Xu, N. Zheng</i>	
ASSESSMENT OF TREES OUTSIDE FORESTS (TOF) AS POTENTIAL FOOD SOURCE IN SECOND DISTRICT, MAKATI CITY	314
<i>J. Dida, K. Quinton, N. Bantayan</i>	

SESSION C4 – NEW GENERATION SENSORS & APPLICATIONS

MONITORING OF URBAN SUBSIDENCE WITH COSMO SKY-MED DATA BY THE PSI TECHNIQUE IN CENTRAL SHANGHAI.....	319
<i>D. Zhang, L. Zhou, J. Wang, H. Li</i>	
MANEUVER IMAGE QUALITY RAISING FOR SJ-9A SATELLITE	325
<i>Y. Liu, F. Li, H. He, C. Yue, Z. Zhao</i>	
RESOLUTION AND MTF STUDIES FOR IMAGES OF OPTICAL REMOTE SENSING SATELLITE.....	335
<i>C. Liu, K.-H. Hsu, J.-R. Tsai, H.-P. Chang</i>	
LOCATION-BASED INFRASTRUCTURE ASSET MONITORING USING MOBILE DEVICES	341
<i>M. Nakagawa, Y. Ogawa, T. Yamamoto, K. Kataoka, Y. Noda, K. Hashimoto, M. Ito, M. Miyo</i>	
GENERATING ROAD SURFACE ORTHOPHOTO FROM IMAGES OF MOBILE MAPPING VEHICLES	347
<i>I.-C. Lee, F. Tsai</i>	

SESSION C5 – INDOOR/3D

MAPPING PADDY RICE CROPPING PATTERNS OF THE MEKONG DELTA USING TIME-SERIES AVHRR DATA	352
<i>Y. Ma, Z. Liu</i>	
3D INDOOR MODEL RECONSTRUCTION USING A PANORAMA EQUIPMENT	358
<i>T.-C. Lin, F. Tsai</i>	
INDOOR MAPPING BASED ON RGB-D AND DSLR CAMERAS	363
<i>T.-S. Wu, F. Tsai</i>	
GEOSPATIAL TECHNOLOGY FOR PEACE: RESOURCE SHARING	369
<i>K. Oo</i>	

SESSION D1 – COASTAL ZONE

CHANGE IN SEAGRASS FRACTIONAL COVER IN BOLINAO AND ANDA, PHILIPPINES DERIVED FROM LANDSAT IMAAGES	370
<i>A. Blanco, A. Tamondong, E. Tagle, M. Fortes, K. Nadaoka</i>	
TELEOS-1 IN MULTI-SOURCE MARITIME SECURITY AND SAFETY APPLICATIONS	376
<i>P. Seah, T. Tan, R. Meurer</i>	
SIMULATION OF THREE-DIMENSIONAL OF WAVE REFRACTION PATTERN USING ENVISAT ASAR DATA	382
<i>M. Marghany</i>	
DEVELOPING GENETIC ALGORITHM FOR SURVYING OF MH370 FLIGHT IN INDIAN OCEAN USING ALTIMETRY SATELLITE DATA	387
<i>M. Marghany</i>	
VARIABILITY OF COASTAL CURRENTS IN THE BAY OF BENGAL DERIVED BY COMBINING SATELLITE ALTIMETRY AND DRIFTER OBSERVATIONS.....	393
<i>B. Peter, K. Mridula, M. Hashim, N. Reba</i>	

SESSION D2 – DATA PROCESSING

TRAINING SITE SELECTION BASED ON UNCERTAINTY ESTIMATION FOR OPTICAL SATELLITE IMAGE CLASSIFICATION	399
<i>Y.-S. Shiu, C.-J. Huang</i>	
A SMART AND ENHANCED MULTI-TEMPORAL SAR INTERFEROMETRY PLATFORM: SKYSENSE-INSAR, DEVELOPMENT AND APPLICATIONS.....	406
<i>X. Hu, H. Liu, F. Chen</i>	
BOUNDARY CLEARNESS OF LAND COVER CLASSIFICATION BY DIFFERENCE OF RESAMPLING METHOD FOR MULTISPECTRAL IMAGE	417
<i>T. Hosomura</i>	
THE CLASSIFICATION OF FOREST TREE SPECIES USING SATELLITE IMAGERY IN MONGOLIA	423
<i>D. Sanjiv, C.-F. Chen, S.-H. Chiang</i>	
ANALYZING THE EFFECTS OF TOPOGRAPHIC WETNESS INDEX ON THE PREDICTIVE ABILITY OF SPECIES DISTRIBUTION MODELS	429
<i>W.-K. Lai, N.-C. Lo, K.-Y. Huang</i>	

SESSION D3 - DISASTER

CHANGE DETECTION OF RICE FIELDS AFTER THE GREAT EAST JAPAN TSUNAMI USING TIME-SERIES MODIS DATA	435
<i>Y.-Y. Hsiao, C.-F. Chen, S.-H. Chiang, N.-T. Son</i>	
PARETO OPTIMALITY FOR MODELLING TSUNAMI EFFECTS ON SEA SURFACE SALINITY FROM MODIS SATELLITE DATA	440
<i>M. Marghany</i>	
PARTICLE SWARM OPTIMIZATION FOR GEOLOGICAL FEATURE DETECTION FROM PALSAR DATA	445
<i>M. Marghany</i>	
LANDSAT 8 INVESTIGATION OF PEAT FIRE DETECTION IN SUMATRA: PRELIMINARY RESULTS	450
<i>C. Elvidge, M. Zhizhin, F.-C. Hsu, K. Baugh, Y. Vetruta, Suwarsono, M. Khomarudin, D. Hilman</i>	
APPROACHES FOR MITIGATING FLOOD DISASTERS UTILIZING REMOTE SENSING INFORMATION	457
<i>T. Sasagawa</i>	

SESSION D4 - CLIMATE

MONITORING RESULTS OF 2013 AND 2014 TRANSBOUNDARY ASIAN DUST EVENTS IN JAPAN USING MODIS DUST INDICES	463
<i>I. Nagatani, J.-I. Kudoh</i>	
SATELLITE BASE APPLICATION FOR FLOOD SIMULATION	469
<i>K. Pakoksung, M. Takagi</i>	
STRUCTURES AND INTENSITY CHANGES OF CONCENTRIC EYE WALL TYPHOONS FROM SATELLITE DATA	475
<i>C.-M. Huang, G.-R. Liu, C.-M. Hsiao, T.-H. Kuo, Y.-T. Yang</i>	
THE RELATIONSHIP BETWEEN AEROSOL OPTICAL DEPTH AND PM FROM SATELLITE AND GROUND-BASED DATA	480
<i>C. Hoi, T.-H. Lin, G.-R. Liu, C.-Y. Liu</i>	
RESEARCH MEDIUM-RESOLUTION SATELLITE IMAGES FOR DROUGHT WARNING IN CENTRAL HIGHLAND, VIETNAM	481
<i>N. Trang, P. Hoa</i>	

SESSION D5 - FORESTRY

MAPPING OF STOCK VOLUME OF DECIDUOUS BROADLEAVED AND EVERGREEN CONIFER FORESTS USING LOW DENSITY LIDAR DATA - A CASE STUDY IN THE UPSTREAM AREA OF DAIHACHIGA RIVER BASIN, GIFU, JAPAN	487
<i>Y. Awaya, N. Fukuda, H. Kawai, T. Takahashi</i>	
IMPACT OF TIDAL HEIGHT ON CHARACTERISTICS OF ALOS PALSAR MEASUREMENTS TO ESTIMATE ABOVE GROUND BIOMASS OF MANGROVE FOREST IN INDONESIA	493
<i>S. Darmawan, W. Takeuchi, V. Vetruta, K. Wikantika, D. Sari</i>	
MODELS FOR ABOVEGROUND FOREST CARBON STOCK ESTIMATION IN TROPICAL REGION USING AIRBORNE LIDAR	499
<i>R. Thapa, M. Watanabe, T. Motohka, M. Shimada</i>	
TRIBAL WOMEN EMPOWERMENT IN SOUTHERN RAJASTHAN	503
<i>D. Rathore</i>	
STUDY ON THE READINESS FOR THE NATIONAL SPATIAL DATA INFRASTRUCTURE DEVELOPMENT IN MYANMAR	507
<i>T. Moe</i>	

SESSION D6 – RS/GIS

LAI ESTIMATION OF WINTER WHEAT USING FOUR SPECTRAL INDICES	508
<i>H. Yang, L. Zhang, T. Shi, H. Jiang, Q. Tong</i>	
SPECTRAL SIGNATURES IN LANDSAT 8 OLI IMAGE AND THEIR INTERPRETATION FOR LAND COVER STUDY	514
<i>N. Duong, L. Anh, H. Thu, N. Anh</i>	
REMOTE ASSESSMENT AND CHANGE DETECTION IN GREEN LAI USING DIFFERENT VEGETATION INDICES	523
<i>G. Shinde, V. Musande</i>	
USING MECHANICAL INTERPOLATION METHOD FOR ORTHO-RECTIFICATION TO GENERATE LARGE SCALE IMAGE MAP FROM HIGH RESOLUTION DATA	533
<i>R. Wei</i>	
DEVELOPMENT OF NATIONAL LEVEL FOREST BASE MAP IN LAO PDR	537
<i>R. Kajiwaru, M. Haraguchi, H. Yamazaki, S. Bounthabandit, S. Panyasak, K. Inthavong, S. Chanthaleusy</i>	

SESSION E1 – COASTAL ZONE

MODELING THE SCATTERING PROPERTIES OF PARTICLE SUSPENSIONS IN SINGAPORE COASTAL WATERS WITH AN ANALYTIC PHASE FUNCTION	543
<i>B. Saengtuksin, C. Chang, S. Liew</i>	
INVESTIGATING THE ACCURACY OF AERIAL TRIANGULATION ON THE BAEKSAJANG BEACH, WEST COAST OF KOREA	544
<i>K.-H. Yun, B. Kim</i>	
LONG-TERM SHORELINE CHANGES ON THE BAEKSAJANG BEACH, WEST COAST OF KOREA	548
<i>B. Kim, K.-H. Yun</i>	
ANALYSIS OF SUBMARINE PHYSIOGRAPHIC FEATURES IN THE BAY OF BENGAL	551
<i>M. Khaing, K. Htun, Z. Lwin</i>	
LAND USE CHANGES OF THE COASTAL ZONE OF OLD TAINAN CITY IN THE PAST HUNDRED YEARS BY USING TEMPORAL SPATIAL INFORMATION	557
<i>J.-T. Chiang, Y.-H. Tseng</i>	

SESSION E2 – INSAR-PROCESSING

REMOTE SENSING AND WAVELET ANALYSIS FOR 30 YEAR NON-LINEAR NON-STATIONARY TELECONNECTION SIGNAL IDENTIFICATION BETWEEN SEA SURFACE TEMPERATURE AND PRECIPITATION REGIME IN CENTRAL AMERICA	563
<i>M. Vazquez, C.-F. Chen</i>	
APPLICATIONS OF RS AND GIS FOR URBAN LAND USE CHANGE STUDIES	571
<i>M. Ganzorig, D. Amarsaikhan, M. Saandar, B. Nergui, B. Byambadolgor</i>	
HOLOGRAM INTERFEROMETRIC SAR AND OPTICAL DATA FOR FOURTH-DIMENSIONAL URBAN SLUM RECONSTRUCTION	576
<i>M. Marghany</i>	
HEIGHT ESTIMATION OF BUILDINGS FROM HIGH-RESOLUTION SAR DATA BASED ON INTERFEROMETRIC ANALYSIS	581
<i>K. Suzuki, W. Liu, F. Yamazaki</i>	

SESSION E3 - DISASTERS

MONITORING MEKONG RIVER LEVEL CHANGE BY SATELLITE ALTIMETRY	587
<i>K.-H. Tseng</i>	
DEVELOPMENT OF A WARNING ASSESSMENT MODEL FOR RAINFALL-INDUCED LANDSLIDES HAZARD BASED ON LANDSLIDE FRAGILITY CURVES	592
<i>M.-H. Hsieh, T.-C. Lei, Y.-M. Huang, B.-J. Lee, R.-Y. Lee</i>	
RAPIDMAP PROJECT FOR DISASTER MONITORING	598
<i>K. Cho, H. Wakabayashi, C. Yang, U. Soergel, C. Lanaras, E. Baltsavias, E. Rupnik, F. Nex, F. Remondino</i>	
FLOOD ANALYSIS AND FORECASTING BY SPATIO-TEMPORAL DATA MINING BASED ON HISTORICAL SATELLITE IMAGE DATABASE.....	604
<i>X. Li, W. Takeuchi</i>	
UTILIZATION OF SPACE BASED TECHNOLOGIES FOR DISASTER RISK REDUCTION (DELTA REGION, MYANMAR)	610
<i>K. Htun, M. Khaing, L. Samarakoon</i>	

SESSION E4 – DATA PROCESSING

AUTOMATIC RECONSTRUCTION OF 3D CITY FROM LIDAR POINT CLOUD DATA	617
<i>Y. Kawata, K. Koizumi</i>	
COMPARISON BETWEEN NIGHTTIME LIGHT AND SOCIOECONOMIC INDICATORS ON AN INTERNATIONAL SCALE USING VIIRS DAY-NIGHT BAND	623
<i>N. Katayama, W. Takeuchi</i>	
VICARIOUS CALIBRATION OF THAICHOTE OVER THAILAND	629
<i>T. Sawangsri, C. Musana, P. Kietleadseere</i>	
THE EVOLUTION OF GISTDA SATELLITE CONTROL CENTER.....	635
<i>W. Vongsantivanich, R. Sachasiri, P. Navakitkanok, J. Plaidoung, D. Niammuad, P. Popattanachai</i>	
SPECTRAL CHARACTERIZATION OF COCONUT SCALE INSECT (CSI) FROM FIELD SPECTRORADIOMETRIC MEASUREMENTS AND HIGH-RESOLUTION SUPERSPECTRAL IMAGERY	640
<i>E. Paringit, J. Fabila, M. Ilagan, C. Cruz, S. Samalburo</i>	

SESSION E5 - GEOLOGY

YANGON SURFACE DISPLACEMENT AS DETECTED BY INSAR TIME SERIES ANALYSIS.....	646
<i>A. Aobpaet, I. Trisrisatayawong, H. Aung, P. Maksin</i>	

ARCHAEOLOGICAL HERITAGE RESOURCE MAPPING: PYU ANCIENT CITIES, MYANMAR	652
<i>M. Mahaxay, K. Win, K. Lwin, B. Hudson</i>	
DETECTING DIFFERENT BORATE MINERAL ZONES IN THE KIRKA BORATE OPEN PIT MINE BY ASTER SATELLITE IMAGES.....	658
<i>C. Ayday</i>	

SESSION E6 – LAND RESOURCES

IMPACTS OF DIRECTIONAL REFLECTANCE ON THE RETRIEVAL AND INTERPRETATION OF SUN- INDUCED CHLOROPHYLL FLUORESCENCE	664
<i>C. Huang, L. Zhang, T. Wu, X. Zhang, Y. Cen, Q. Tong</i>	
LAND DEGRADATION MODELLING IN INACCESSIBLE MOUNTAINOUS AREAS IN THE TROPICS	670
<i>D. Shrestha</i>	
GEOGRAPHIC INFORMATION AND REMOTE SENSING: ESSENTIAL TOOLS IN REDUCING POVERTY IN THE POST-2015 WORLD.....	676
<i>R. Ryerson</i>	
DOWNSCALING ADVANCED MICROWAVE SCANNING RADIOMETER 2 SURFACE SOIL MOISTURE USING NORMALIZED MULTI-BAND DROUGHT INDEX AND LEAF AREA INDEX	681
<i>H. Lien, C. Chen, S. Chiang</i>	
REMOTE SENSING OF GLOBAL AND REGIONAL LAND DEGRADATION PROCESSES FOR IMPROVED LAND GOVERNANCE	687
<i>G. Metternicht</i>	

SESSION F1 – COASTAL ZONE

ESTABLISHING AND STANDARDIZING SHORELINE ON SATELLITE IMAGES	695
<i>N. Hieu, P. Canh, D. Phuong</i>	
HYBRID GENETIC ALGORITHM FOR THREE DIMENSIONAL PHASE UNWRAPPING FOR SIMULATION OF VOLUME CHANGE OF SHORELINE.....	701
<i>M. Marghany</i>	
COSMO-SKYMED FOR AUTOMATIC DETECTION OF OIL SPILL USING ON MULTI-OBJECTIVE EVOLUTIONARY ALGORITHM ALONG GULF OF THAILAND	706
<i>M. Marghany</i>	
MAPPING SEAGRASS BED IN THUY TRIEU LAGOON (VIETNAM) BY USING LANDSAT 8 IMAGE	711
<i>V.-K. Lau, C.-F. Chen, H.-S. Phuoc, X.-V. Nguyen</i>	
SATELLITE-BASED BENTHIC HABITAT MAPPING USING LANDSAT 8 IN NUSA LEMBONGAN AND NUSA CENINGAN ISLAND, BALI	716
<i>F. Pramudya, W. Windupranata, K. Wikantika</i>	

SESSION F2 – DATA PROCESSING

ACCURACY ASSESSMENT OF GLOBAL TOPOGRAPHIC DATA (SRTM & ASTER GDEM) IN COMPARISON WITH LIDAR FOR TROPICAL MONTANE FOREST	722
<i>W. Wong, S. Tsuyuki, K. Ioki, M.-H. Phua</i>	
COMPARISON OF NORMALIZED CROSS CORRELATION AND MUTUAL INFORMATION FOR FEATURE LINE MATCHING	728
<i>J.-Y. Yen, L.-C. Chen</i>	
GEOMORPHOLOGICAL CHANGE ANALYSIS OF BAZHANG RIVER CHANNEL WITH HISTORIC PHOTOGRAPHS	731
<i>P. Shih</i>	
EVALUATION OF UNCERTAINTY IN CLASSIFICATION ACCURACY.....	734
<i>S. Lawawirojwong, T. Suepa, J. Qi</i>	
A COMPARISON AND COMBINATION OF METHODS FOR CO-REGISTRATION OF MULTI-MODAL IMAGES	740
<i>C. Lanaras, E. Baltsavias, K. Schindler</i>	

SESSION F3 – CLIMATE/DISASTER

SPATIAL ASSESSMENT OF CLIMATE CHANGE IMPACT FOR DENGUE FEVER DISEASE DISTRIBUTION IN EAST JAVA PROVINCE: CASE STUDY UTILIZATION OF GEOSPATIAL INFORMATION FOR PUBLIC HEALTH	747
<i>J. Suryanta, S. Niendyawati</i>	
AN IMPROVED METHOD FOR CALIBRATION AND VALIDATION OF MODIS CHLOROPHYLL-A IN THE NORTH MALACCA STRAITS.....	753
<i>M. Reba, N. Lah, E. Siswanto, K. Tanaka</i>	
MAPPING THE POTENTIAL RISK OF LANDSLIDES IN CIAMIS DISTRICT, WEST JAVA	759
<i>A. Suriadi, M. Arsjad</i>	

A SATELLITE-BASED EARLY WARNING SYSTEM FOR PEATLAND FIRES TOWARD SUSTAINABLE PALM OIL IN INDONESIA	765
<i>N. Yulianti, B. Barbara, E. Firdara</i>	
A GEOGRAPHICAL MODEL FOR PREDICTION OF MALARIA INDEX ON AYEYARWADY REGION	770
<i>A. Khine</i>	

SESSION F4 - CLIMATE

ESTIMATION OF GLOBAL CO₂ EMISSION FROM SOIL USING TEMPERATURE AND WATER CONTENT MEASURED BY MODIS	776
<i>M. Adachi, A. Ito, W. Takeuchi</i>	

VOLUME 2

THE ROLE OF GEO-SPATIAL DATA AND INFORMATION IN POLICY MAKING FOR CLIMATE CHANGE RELATED DISASTERS	780
<i>G. Metternicht, M. Leclerc, S. Giada</i>	
INFERRING CO₂ SOURCE REGIONS USING A LAGRANGIAN TRANSPORT MODEL AND GOSAT RETRIEVED PROFILES	787
<i>R. Macatangay, F. Schwandner, V. Velazco, C. Gerbig, T. Sonkaew, T. Yokota</i>	
GEOMETRIC ACCURACY INVESTIGATIONS OF AVHRR ORTHOIMAGES	791
<i>S. Aksakal, E. Baltasvias, K. Schindler</i>	
CLIMATE CHANGE TRENDS AND ASSOCIATED ENVIRONMENT IMPACT IN UDAIPUR BASIN OF RAJASTHAN, INDIA	797
<i>N. Rathore, D. Rathore, N. Verma</i>	

SESSION F5 - GEOLOGY

THE APPLICATION OF LANDSAT-8 OLI/TIRS DATA FOR GEOLOGICAL MAPPING: A CASE STUDY FROM SE IRAN	803
<i>A. Pour, M. Hashim</i>	
GEOLOGICAL STRUCTURE MAPPING FOR GOLD EXPLORATION TARGETS USING PALSAR REMOTE SENSING DATA IN THE CENTRAL GOLD BELT, PENINSULAR MALAYSIA	809
<i>A. Pour, M. Hashim</i>	
THE KALAHARI IMPACTS HYPOTHESIS FOR MOON GENESIS - DID THE MOROKWENG METEORITE IMPACT (145MA) BREAK UP THE GONDWANALAND AND LET CONTINENTAL FLUID BASALT (CFB) DISCHARGE TO FORM THE MOON?-	814
<i>K. Tokumaru</i>	
DEFORMATION MONITORING IN THE METRO MANILA BY INSAR TECHNIQUE USING PALSAR DATA	820
<i>T. Deguchi</i>	
A CLOUD-BASED PLATFORM FOR GEOLOGICAL DATA ACQUISITION VIA MOBILE DEVICE	826
<i>A. Harfield, S. Homhuan, C. Humhong, U. Phattharanamchok, S. Korbut</i>	

F6 – WATER RESOURCES

APPLICATION OF REMOTE SENSING AND GIS FOR PREVENTION-RISK WARNING OF MALARIA IN GIA LAI AREAS	832
<i>P. Hong, P. Hoa, P. Canh</i>	
APPLICATION OF REMOTE SENSING AND GAUGED PRECIPITATION INFORMATION FOR IMPROVING HOURLY TYPHOON RAINFALL FORECASTING OF WRF	838
<i>P.-S. Yu, J.-W. Chen, Y.-C. Lin, C.-M. Kuo, T.-C. Yang, Z. Yuan</i>	
CALIBRATION OF HYDROLOGICAL STREAMFLOW MODELING USING MODIS	840
<i>M. Mahaxay, W. Arunpraparut, Y. Trisurat, N. Tangtham</i>	
QUICKBIRD IMAGERY FOR SUPPORT TO MAPPING OF SALT LAND SUITABILITY IN KUPANG BAY, EAST NUSA TENGGARA PROVINCE - INDONESIA	846
<i>Y. Suwarno</i>	
DEVELOPMENT OF GEOSPATIAL TOOLS FOR TIDAL CURRENT ENERGY RESOURCE ASSESSMENT: A CASE OF VERDE ISLAND PASSAGE, PHILIPPINES	852
<i>M. Ang</i>	

SESSION G1 – HYPERSPECTRALSENSING CLASSIFICATION & APPLICATION

EVALUATION OF PROJECTION MODEL FOR RANDOM POINT CLOUD	858
<i>K. Kataoka, M. Nakagawa</i>	

IMPROVEMENT OF ESTIMATION METHOD FOR GRAMINEOUS CROP PRODUCTIVITY USING NORMALIZATION OF HYPERSPECTRAL DATA	864
<i>S. Odagawa, A. Nakazawa, T. Takeda</i>	
EVALUATION OF THE EFFECTS OF CONTINUUM REMOVAL ON THE ACCURACY OF MINERAL SPECTRAL UNMIXING MODELS	870
<i>H. Zhao, L. Zhang</i>	
FEATURE EXTRACTION AND CLASSIFICATION OF HYPERSPECTRAL IMAGES	876
<i>A. Munkh-Erdene, M. Ganzorig</i>	
INTEGRATION OF AIRBORNE HYPERSPECTRAL IMAGERY AND AIRBORNE LIDAR POINT CLOUDS FOR OBJECT-BASED CLASSIFICATION	881
<i>J.-S. Huang, T.-A. Teo</i>	

SESSION G2 – URBAN

BUILDING CLASSIFICATION USING AIRBORNE LIDAR DATA WITH SATELLITE SAR DATA	882
<i>T. Yamamoto, M. Nakagawa</i>	
URBAN MORPHOLOGY ANALYSIS BY REMOTE SENSING AND GIS TECHNIQUE, CASE STUDY: GEORGETOWN, PENANG	888
<i>M. Nor, N. Noor</i>	
ASSESSMENT OF URBAN TEMPERATURE SPATIAL DISTRIBUTION BASED ON EFFECTIVE INDICES USING SATELLITE IMAGERY AND GROUND TRUTH DATA(A CASE STUDY TEHRAN CITY)	894
<i>M. Reveshty, A. Rewaz</i>	
REMOTE SENSING OF URBAN ECOLOGICAL INFRASTRUCTURE IN DESAKOTA ENVIRONMENTS: A REVIEW OF CURRENT APPROACHES	902
<i>S. Hawken, G. Metternicht, C. Chang, S. Liew, A. Gupta</i>	
ORIENTATION DETERMINATION OF UAV IMAGES USING POINT AND LINE CONTROL	910
<i>C.-H. Hung, L.-C. Chen</i>	

SESSION G3 – INNOVATIVE UAV APPLICATIONS

URBAN STRUCTURAL DAMAGE ASSESSMENT WITH OBLIQUE UAV IMAGERY, OBJECT-BASED IMAGE ANALYSIS AND SEMANTIC REASONING	913
<i>N. Kerle, J. Galarreta, M. Gerke</i>	
QUALITY ASSESSMENT OF IMAGE MATCHERS FOR DSM GENERATION – A COMPARATIVE STUDY BASED ON UAV IMAGES	919
<i>R. Qin, A. Gruen, C. Fraser</i>	
DEVELOPMENT OF HYPERSPECTRAL IMAGING SENSOR, WHICH MOUNTED ON UAV FOR ENVIRONMENTAL STUDY AT COASTAL ZONE	926
<i>G. Saito, H. Seki, K. Uto, Y. Kosugi, T. Komatsu</i>	
EVALUATING, MAPPING, AND MANAGING UNPAVED ROAD NETWORKS USING HIGH-RESOLUTION REMOTE SENSING DATA	930
<i>C. Singh, C. Brooks, R. Dobson, C. Roussi, T. Colling, D. Dean, M. Watkins</i>	
UAV-BASED GAS PIPELINE LEAK DETECTION	936
<i>T. Bretschneider, K. Shetti</i>	

SESSION G4 - WEBGIS

TOWARDS VISUALIZING CANAL CROSS-SECTION USING DATA ACQUIRED FROM TELEOPERATED BOAT	942
<i>S. Tanathong, K. Rudahl, S. Goldin</i>	
MAPPING TECHNOLOGY WITH TWO SPHERICAL CAMERAS AND ITS APPLICATIONS	948
<i>S. Nakamura, L. Zheng, T. Ichihashi</i>	
OPEN SOURCE AND OPEN STANDARDS: TOOLS FOR RAPID DEVELOPMENT OF COMMUNITY-ORIENTED GIS	954
<i>S. Goldin, K. Rudahl, P. Intapong</i>	
THE DEVELOPMENT OF AN INTEGRATED AND CONTEXT-AWARE WEBGIS OF ALERTING INFORMATION	960
<i>S.-C. Chen, J.-H. Hong</i>	
ASSESSMENT OF CLOUD AREA USING FIELD SERVER AND IMAGE PROCESSING	972
<i>T. Sritarapipat, P. Rakwatin, T. Pechprasarn</i>	

SESSION G5 – FOREST/LAND RESOURCES

RICE PRODUCTION FORECASTING FROM MODIS NDVI DATA IN SYLHET REGION OF BANGLADESH	978
<i>N. Deshapriya, M. Mahboob, A. Hasan, M. Hazarika, L. Samarakoon</i>	
COMPILATION OF A REMOTE SENSING IMAGE FUSION ATLAS	985
<i>C. Pohl, T. Yen</i>	

FOREST RESOURCES MAPPING IN MONGOLIA USING MULTISOURCE IMAGES.....	991
<i>D. Amarsaikhan, V. Battsengel, E. Egshiglen, D. Enkhjargal</i>	
DETECT LAND COVER CHANGE BY USING NDVI DIFFERENCING AND POSTCLASSIFICATION: A CASE STUDY IN HOA BINH - VIETNAM.....	996
<i>N. Hanh, T. Dien</i>	
BRIDGING KNOWLEDGE AND SCIENCE TO SUSTAINABLE DEVELOPMENT POLICY: THE ROLE OF GEOSPATIAL TECHNOLOGIES.....	1008
<i>G. Metternicht</i>	

SESSION G6 – NATURAL RESOURCE MANAGEMENT

THE APPLICATION OF SATELLITE REMOTE SENSING TECHNIQUES FOR MONITORING MANGROVE FOREST IN YAMBYE TOWNSHIP, RAKHINE STATE, MYANMAR.....	1015
<i>H. Aye</i>	
FRACTAL ANALYSIS FOR RADIOISOTOPE POLLUTION PATTERNS BY NUCLEAR POWER PLANT ACCIDENTS.....	1021
<i>S. Ogawa, K. Saito</i>	
GEO-INFORMATICS FOR NATIONAL DEVELOPMENT PLANNING: EXPERIENCE OF BHUTAN.....	1027
<i>M. Mying, A. Rai</i>	
ASSESSMENT OF FIRE VULNERABILITY THROUGH HUMAN ACTIVITY BY USING ROAD DISTRIBUTION IN PEAT LAND OF INDONESIA.....	1035
<i>H. Park, W. Takeuchi, Sonidarmawan</i>	
APPLICATION OF GEO-INFORMATICS FOR DESIGNING NATIONAL FOREST INVENTORY SYSTEM AND FOREST RESOURCES POTENTIAL ASSESSMENT OF BHUTAN.....	1041
<i>M. Myint, K. Tshering, A. Rai</i>	

SESSION H1 – LAND RESOURCES

NSDI AS AN ENABLING PLATFORM FOR FACILITATION OF LAND ADMINISTRATION FUNCTIONS IN VIET NAM.....	1048
<i>B. Thanh, M. Huy, P. Hai, V. Tuan</i>	
AGENT-BASED MODEL ANALYSIS OF LANDOWNER’S MOTIVATION IN LAND USE CHANGE FROM HOME GARDEN AT KANDY CITY IN SRI LANKA.....	1054
<i>H. Jonai, W. Takeuchi, H. Hearath, L. Samarakoon</i>	
GLOBAL CHANGE OBSERVATION MISSION (GCOM).....	1058
<i>H. Shimoda, Y. Otake</i>	
THE CHALLENGES OF CONSTRUCTING A SENSOR WEB DATA STREAM MANAGEMENT SYSTEM.....	1064
<i>C.-Y. Huang, S. Liang</i>	
THE SOCIOECONOMIC DRIVERS OF LAND COVER DYNAMICS IN THE LI RIVER BASIN, CHINA.....	1070
<i>Y. Zhang, Q. Qin, R. Xu, C. Lin, J. Li</i>	

SESSION H2 – NEW GENERATION SENSORS & APPLICATIONS

MINI SATELLITE REMOTE SENSING – A CONVERGENCE OF INNOVATION AND POLICIES.....	1076
<i>K. Tin</i>	
CONTAINER TRACKING VIA AIS SATELLITES.....	1081
<i>R. Timo, T. Nguyen</i>	
ADVANCED SMALL SATELLITE CONSTELLATIONS FOR EARTH OBSERVATION SERVICES.....	1086
<i>M. Sweeting, D. Hodgson, P. Yi</i>	
A NEW APPROACH TO GROUND INFRASTRUCTURE - KSAT SMALL ANTENNA NETWORK.....	1095
<i>K. Olafsson, M. Krynitz</i>	
INCLINED SATELLITE ORBITS AND RESULTING GROUND STATION NETWORK SOLUTIONS FOR NEAR EQUATORIAL AREAS.....	1101
<i>M. Krynitz, K. Olafsson</i>	

SESSION H3 – NEW GENERATION SENSORS & APPLICATIONS

EFFECTS OF THE INCIDENCE ANGLE AND SURFACE TYPE ON THE LIDAR INTENSITY VALUE.....	1102
<i>Y.-T. Wu, C.-K. Wang</i>	
DIGITIZING 60 METERS OF FULL WAVEFORM LIDAR IN A DENSE TROPICAL RAINFOREST.....	1108
<i>M. Isenburg, H. Trunzer, F. Malmer</i>	
LANDSLIDE MONITORING BY LIDAR AND DIGITAL CAMERA WITH BAND PATH FILTERS.....	1114
<i>K. Sugiyama, S. Akiyama, M. Takagi</i>	
RELEVANCE OF VEGETATION INDICES FROM MULTISPECTRAL IMAGE AND AIRBORNE FULL-WAVEFORM LIDAR IN URBAN AREA.....	1119
<i>H.-M. Wu, T.-A. Teo</i>	

RESEARCH ON MAPPING LEVEE LINES USING LIDAR DATA IN THE NAKDONG RIVER BASINS, SOUTH KOREA	1125
<i>Y. Choung</i>	

SESSION H4 – NEW GENERATION SENSORS & APPLICATIONS

STRATEGIES TO PROMOTE THE APPLICATION OF SATELLITE REMOTE SENSING IN EMERGING AREAS	1130
<i>W. Ning, J. Li, Y. Yuan, X. Jia</i>	
CONSTELLATION DESIGN AND DEPLOYMENT STRATEGY OF TAIWAN REMOTE SENSING SATELLITES	1132
<i>C.-W. Hsueh, C. Liu, F.-T. Hwang</i>	
INDIAN REMOTE SENSING SATELLITES: IN ORBIT AND PLANNED SATELLITES	1138
<i>D. Murthy, M. Paul</i>	
THE ROLE OF SMALL SATELLITES IN SUSTAINABLE DEVELOPMENT AND IN NATIONAL EARTH OBSERVATION SYSTEMS	1142
<i>A. Curiel, A. Cawthorne, K. Wisniewska, M. Sweeting</i>	

SESSION H5 – CAPACITY BUILDING & SATELLITE PROGRAM

RICE YIELD ESTIMATION WITH SATELLITE DATA	1148
<i>N. Son, C. Chen</i>	
THE EVALUATION OF LAND TO AGRICULTURE IN BANGGAI REGENCY	1153
<i>B. Riadi, W. Ambarwulan</i>	
INNOVATIVE RESEARCH IN REMOTE SENSING APPLICATIONS FOR GEOSPATIAL SOLUTIONS AT UNIVERSITI TEKNOLOGI MALAYSIA	1160
<i>M. Hashim</i>	
EARTH OBSERVATION: FROM SYSTEMS TO SERVICES AND FROM IN-ORBIT CAMERAS TO VALUE- ADDED PRODUCTS	1165
<i>M. Siguier</i>	
DEVELOPMENT OF INTEROPERABLE MULTI-SATELLITE OPERATIONS PLATFORM	1166
<i>S.-C. Chou, M.-C. Cheng, B. Chen, P.-H. Huang</i>	

SESSION H6 – DISASTER & CLIMATE

ONE LAPTOP, ONE WEEKEND AND 4,000 ULTRACAMX LARGE FORMAT AERIAL PHOTO	1172
<i>D. Stanley, P. Cheng</i>	
SURFACE DEFORMATION FROM MULTI-TEMPORAL INSAR METHODS WITH ALOS PALSAR IN PINGTUNG PLAIN	1178
<i>C.-Y. Lee, W.-C. Hung, C. Hwang</i>	
ATMOSPHERIC CORRECTION FOR ESTIMATION OF ABOVE-GROUND CROP BIOMASS – A COMPARISON	1183
<i>N. Hieu, J. Hung, S. Zhao, J. Heo</i>	
COMPARISON ANALYSIS OF CH4 ESTIMATIONS FROM BIOPHYSICAL MODELING, SATELLITE MEASUREMENT AND INVENTORY DATA IN SIBERIAN NATURAL WETLAND	1188
<i>W. Takeuchi, S. Hayashida, R. Imasu, S. Suresurige</i>	
CALIBRATION FACILITY FOR ANALYSING LOCATIONAL AND DETECTABILITY ACCURACIES OF GROUND PENETRATING RADAR	1189
<i>S. Jaw, M. Hashim</i>	

SESSION PS-1

COMPARISON STUDY ON SOLAR IRRADIANCE SPECTRA FOR COMS MI APPLICATION OF HELIOSAT	1195
<i>A. Song, W. Choi, N. Lee, Y. Kim</i>	
MODIFIED METHOD OF CLOUD INDEX ESTIMATION FOR DERIVING SOLAR IRRADIANCE BY USING HELIOSAT-II METHOD	1200
<i>W. Choi, A. Song, C. Yun, Y. Kim</i>	
MULTI-TEMPORAL VIRTUAL 3D CAMPUS INTEGRATED WITH HISTORIC GIS DATA	1205
<i>F. Tsai, Y.-C. Liu, L.-C. Chen</i>	
A PRELIMINARY STUDY ON USING NDVI AND NDWI TIME SERIES FOR MONITORING ABANDONED FARMLANDS IN MOUNTAIN AREAS	1209
<i>A. Sakuma, H. Shimazaki</i>	
SPATIAL EXTENT OF THE BROWN PLANTHOPPER (BPH) NILAPARVATA LUGENS (STAL.) IN FOUR PROVINCES OF CENTRAL THAILAND	1215
<i>L. Abril, E. Nawata</i>	

CROPLAND CLASSIFICATION FROM MODIS-LANDSAT FUSION DATA	1220
<i>H.-Y. Fang, C.-F. Chen, S.-H. Chiang, N.-T. Son, C.-R. Chen, L.-Y. Chang</i>	
STUDY ON THE CREATION OF ULTRAVIOLET DISTRIBUTION MAP USING SATELLITE IMAGES.....	1226
<i>T. Ishiuchi, M. Takata, H. Nakazawa</i>	
CHARACTERIZATION OF COLUMNAR WATER VAPOR MEASUREMENTS AND ITS COMPARISON WITH MODEL ESTIMATES AND SURFACE METEOROLOGICAL PARAMETERS OVER MANILA, PHILIPPINES (14.567°N, 120.980°E).....	1230
<i>R. Castilla, F. Plando, E. Vallar, M. Galvez, V. Morris</i>	
AEROSOL OPTICAL THICKNESS AND TOTAL OZONE COLUMN CHARACTERIZATION USING MICROTOPS II OZONEMETER IN MANILA, PHILIPPINES.....	1236
<i>F. Plando, R. Castilla, E. Vallar, M. Galvez</i>	
RECOGNITION OF PEDESTRIANS AND VEHICLES BASED ON PRINCIPAL COMPONENT ANALYSIS	1241
<i>M. Wu, W. Shi, K. Gong</i>	
LANDSLIDE MONITORING BY LIDAR AND DIGITAL CAMERA WITH BAND PATH FILTERS	1247
<i>L.-C. Chen, Y.-X. Lan, W.-C. Chang</i>	
URBAN ROAD EXTRACTION FROM OPTICAL REMOTELY SENSED IMAGERY	1250
<i>S.-C. Peng, H. Ren</i>	
SAR IMAGE SIMULATION FOR GEOMETRIC AND RADIOMETRIC TERRAIN CORRECTION	1256
<i>C.-C. Lau, T.-K. Chen, T.-Y. Liao, K.-H. Lo, Q.-X. Huang</i>	
DETECTION AND CORRECTION OF ASTER GDEM V2 DATA ANOMALIES THROUGH DEM DIFFERENCING	1261
<i>J. Santillan, M. Santillan</i>	
APPLICATION OF SWARM INTELLIGENCE FOR LANDSLIDE SUSCEPTIBILITY MODELING FROM GEOSPATIAL DATA FUSION	1267
<i>J.-S. Lai, F. Tsai</i>	
GIS-BASED LANDSLIDE SUSCEPTIBILITY MAPPING IN LANTAU ISLAND, HONG KONG BY FREQUENCY RATIO AND LOGISTIC REGRESSION MODEL	1273
<i>J. Huang, Q. Zhou</i>	
INTEGRATED REMOTE SENSING AND GIS FOR LANDSLIDE RESEARCH IN BAC KAN PROVINCE BY COMBINING ANALYTIC HIERACHY PROCESS AND BIVARIATE STATISTICAL ANALYSIS APPROACH	1275
<i>T. Dinh, N. Thach</i>	
RESEARCH ON THE EXTRACTION ACCURACY IMPROVEMENT OF MANGROVE FORESTS	1281
<i>Y. Kuwahara, T. Ishiuchi, H. Yokoki</i>	
FOREST CARBON STOCK ESTIMATION USING ALOS/PRISM IN MYANMAR.....	1284
<i>Y. Wada, N. Mitsuzuka, T. Oo, M. Mon</i>	
NATIONWIDE TRENDS OF FOREST DISTRIBUTION USING SPOT VEGETATION TIME SERIES APPROACH IN CASE OF MYANMAR	1290
<i>N. Mitsuzuka, Y. Wada, T. Oo, M. Mon</i>	
CHANGE DETECTION OF MANGROVE FORESTS IN WEST AND CENTRAL AFRICA WITH LANDSAT IMAGERY	1296
<i>T.-T. Dan, C.-F. Chen, S.-H. Chiang, N.-T. Son, C.-R. Chen, L.-Y. Chang</i>	
ESTIMATING ABOVE-GROUND BIOMASS OF CORN BY COMBINING SATELLITE IMAGERY AND FIELD INVENTORY	1302
<i>N. Hieu, J. Jung, J. Kim, S. Zhao, J. Heo</i>	
ANALYZING THE TEMPORAL VARIATIONS OF NET PRIMARY PRODUCTIVITY OF TAIPEI CITY THROUGH REMOTE SENSING.....	1307
<i>C.-C. Cheng</i>	
FOREST RESOURCES BALANCE AND IT'S ECONOMIC VALUATION AT BUOL REGENCY, CENTRAL SULAWESI PROVINCE, INDONESIA BY USING GEOGRAPHICAL INFORMATION SYSTEM AND BENEFITS TRANSFER METHOD	1313
<i>I. Nahib</i>	
A PRIORI STUDY OF USING SPATIAL DATA MINING TECHNOLOGY WITH FORMOSAT-2 IMAGERY FOR ANALYZING POTENTIAL LANDSLIDE-CAUSING FACTORS	1319
<i>C.-C. Yeh, P.-H. Hsu, Y.-L. Chang, T.-Y. Chang</i>	
GROUND SURFACE CHANGES DETECTION AT GEOTHERMAL SURFACE MANIFESTATIONS USING MULTI-TEMPORAL LANDSAT IMAGERIES	1325
<i>B. Nugraha, A. Saepuloh, K. Wikantika</i>	
SURFACE ROUGHNESS MODELING USING POLARIMETRIC SAR DATA TO DELINIATE GEOMORPHOLOGIC OF MINERALIZATION ZONES AT VOLCANIC TERRAIN.....	1331
<i>F. Anugrah, A. Saepuloh, K. Wikantika</i>	
A STUDY OF NORMALIZING TOA RADIANCE METHOD FOR EARTH OBSERVATION SATELLITES WITH SIMILAR SPECTRAL BANDWIDTH.....	1337
<i>C.-G. Jin, H.-S. Lim, S.-G. Lee</i>	

SESSION PS-2

EVALUATION OF MEDIAN FILTERING IMPACT ON SATELLITE-BASED SUBMERGED SEAGRASS MAPPING ACCURACY IN TROPICAL COASTAL WATER	1341
<i>S. Misbari, M. Hashim</i>	

THE APPLICATION OF VGI ON SPATIAL CLUSTER ANALYSIS OF TRAFFIC INCIDENTS	1347
<i>Y.-C. Kao, C.-H. Wei, Y.-C. Chuang, T.-C. Lei</i>	
USING OF CLOSE RANGE PHOTOGRAMMETRY IN IMAGE BASED MODELLING FORM FOR ARCHAEOLOGY	1353
<i>K. Pavelka, J. Reznicek, E. Matouskova, M. Faltynova</i>	
ENHANCEMENT METHODS FOR MAPPING THE BOUNDARIES OF SUBMERGED ROCKS IN SHALLOW WATERS WITH WORLDVIEW-2 IMAGES.....	1359
<i>J.-K. Liu, T.-Y. Lin, W.-C. Hsu</i>	
USING MULTI-TEMPORAL GEOMORPHOLOGICAL DATA TO ASSESS THE DENUDATION RATE AND EROSION CHARACTERISTICS OF GUTINGKENG MUDSTONE IN SW TAIWAN	1365
<i>H.-C. Chang, Q.-C. Sung</i>	
RPAS AS A TOOL FOR THE RESEARCH, DOCUMENTATION AND MONITORING.....	1372
<i>K. Pavelka, J. Reznicek, E. Matouskova, M. Faltynova</i>	
DEVELOPMENT OF A SMART DEVICE-BASED TELEMETRY AND PHOTOGRAPING SYSTEM FOR PHOTOGRAMMETRIC UAV SYSTEM ON NON-VISIBLE AREA.....	1378
<i>J. Park, M. Kim, D. Shin, C. Choi</i>	
LOCATION SUITABILITY ANALYSIS OF ENVIRONMENTAL EDUCATION FACILITIES.....	1384
<i>P.-C. Yang, S.-F. Wang</i>	
GEOSPATIAL PATTERNS ANALYSIS OF TRAFFIC ACCIDENTS IN JINJU, KOREA.....	1390
<i>B. Sung, H. Yoo</i>	
FIRE RISK ASSESSMENT ON THE LAND USE ZONING IN KOREA	1396
<i>G. Bae, H. Yoo</i>	
A SERVICE DISTRICT ANALYSIS ON HEALTH CARE FACILITIES IN A LOCAL CITY OF KOREA.....	1401
<i>M. Kim, H. Yoo</i>	
NON-METRIC DIGITAL CAMERAS OF ZOOM-DEPENDENT IMAGE POINT REFINEMENT	1406
<i>T.-L. Chou, J.-J. Jaw</i>	
NUMERICAL APPROACH FOR ANALYZING CRITICAL CONFIGURATIONS OF SINGLE PHOTO RESECTION.....	1412
<i>H.-C. Li, J.-J. Jaw</i>	
PRELIMINARY STUDY ON SPACE-BORNE LASER ALTIMETER SUPPORTED AEROTRIANGULATION.....	1418
<i>C. Yue, H. He, Y. Bao, K. Xing, N. Zhou</i>	
A PRELIMINARY STUDY OF A NEW X-BAND SAR SATELLITE MISSION FOR TAIWAN	1423
<i>C.-L. Chang, B.-H. Wu, M.-C. Lin, J. Yaung, S.-J. Yu, P.-J. Yang, I.-Y. Tarn, S.-L. Chen</i>	
MONITORING RESPONSIBLE RESOURCE DEVELOPMENT AND COMMUNITY LAND-USE USING MULTI-DATE RAPIDEYE DATA.....	1428
<i>O. Tsui, A. Dean, B. Pierce, A. Syed, G. Lavoie, T. Boivin</i>	
AN IMPROVED DTBS METHOD FOR AUTOMATIC TRAFFIC SIGN RECOGNITION.....	1433
<i>T.-H. Juan, J.-Y. Han</i>	
EFFECT OF WATER PROPERTY ON DEPTH MEASUREMENTS BY AIRBORNE LIDAR BATHYMETRY	1439
<i>H.-Y. Cheng, J.-J. Jaw</i>	
GLOBAL LAND COVER CLASSIFICATION USING SURFACE REFLECTANCE PRODUCTS	1445
<i>A. Koyama, K. Fukue, Y. Otake, H. Shimoda</i>	
HISTORICAL AERIAL PHOTOGRAPHS USED FOR ANALYZING TOPOGRAPHIC CHANGES OF HSIAOLIN LANDSLIDE AREA	1450
<i>J.-K. Liu, H.-C. Chang, W.-C. Hsu</i>	
USING REMOTE SENSING AND GIS TO BUILD VEGETATION STATUS MAP FOR PHU LOC DISTRICT, THUA THIEN HUE PROVINCE, VIETNAM.....	1456
<i>H. Nguyen, V. Nguyen, N. Ho, N. Hoang</i>	
UTILIZATION OF RS DATA AND GIS FOR ACCELERATING ADMINISTRATION BOUNDARIES DELIMITATION: CASE STUDY CENTRAL KALIMANTAN PROVINCE, INDONESIA.....	1464
<i>N. Supardan, L. Hidayatno</i>	
VISUAL VERIFICATION OF CIVIL ENGINEERING STRUCTURES BY UAV	1469
<i>T. Kosaka, M. Tokunaga</i>	
LEAST SQUARES MULTIPLE IMAGES MATCHING FOR LARGE COVERAGE AERIAL IMAGE AND SMALL COVERAGE UAV IMAGE.....	1473
<i>K.-Z. Zhan, T.-A. Teo</i>	
RESEARCH ON URBAN CHANGES IN A RELATIONSHIP WITH GEOGRAPHICAL FACTORS IN THE WESTERN REGION OF HANOI DURING THE PERIOD 2000-2014	1480
<i>D. Bac, N. Thanh, L. Tuyet</i>	
EXPERIMENTAL AND ANALYTICAL STUDY OF INVISIBLE WATER LEAKS DETECTION USING GROUND PENETRATING RADAR	1486
<i>L. Lee, S. Jaw, M. Hashim</i>	
ANALYSIS OF URBAN HEAT ISLAND INTENSITY AND ITS IMPACT ON REGIONAL PRECIPITATION OVER TAINAN CITY IN TAIWAN	1492
<i>W. Yen, T. Lin, G. Liu, C. Liu</i>	
BUILDING CONCRETE CRACKS DETECTION USING IMAGE-BASED NON-DESTRUCTIVE GEOTECHNICAL TECHNIQUE	1498
<i>H. Ng, M. Hashim, S. Jaw</i>	

SPATIAL DISTRIBUTION PATTERNS OF CLEAN WATER SYSTEM BASED ON GIS SPATIAL ANALYSIS IN THE NAKDONG RIVER BASIN OF SOUTH KOREA : FOCUSED ON INDICATOR SPECIES	1504
<i>M. Jo, M. Byun, S. Jang, H. Shin, J. Sim</i>	
DETECTING FOREST CHANG AND DISTURBANCE IN THE TOLEDO DISTRICT	1506
<i>S. Chicas, K. Omine, P. Saqui</i>	

SESSION PS-3

A RAPID MATCHING APPROACH FOR LARGE-SCALE URBAN IMAGERY	1512
<i>X. Yang, X. Qin, J. Wang, X. Ye, J. Wang, Q. Qin</i>	
CONSTRAINT-BASE LIDAR POINT CLOUD FITTING	1518
<i>Y.-C. Chen, J.-Y. Chen, H.-C. Tsao, C.-H. Lin</i>	
SMART CAMERA CALIBRATION FOR PHOTOGRAMMETRY APPLICATION	1524
<i>H. Jeong, H. Ahn, C. Choi</i>	
SPATIAL ANALYSIS OF THE TAEAN SHORELINE CHANGE USING SATELLITE IMAGE AND GIS.....	1528
<i>J. Choi, C. Choi, M. Yun, H. Ahn</i>	
STUDY OF SURFACE TEMPERATURE WITH LAND COVER CHANGE USING LANDSAT	1532
<i>H. Ahn, J. Choi, D. Shin, C. Choi</i>	
LAND USE AND LAND COVER CLASSIFICATION MAPPING BASED ON BAND RATIOING WITH SUBPIXEL OF SUPPORT VECTOR MACHINE TECHNIQUES (A CASE STUDY ON NGAMOEYEIK DAM AREA, YANGON REGION)	1536
<i>K. Yee, K. Wai, C. Uong</i>	
BUILDING STRUCTURAL CORNER DETECTION USING HIGH RESOLUTION OBLIQUE AIRBORNE IMAGES	1541
<i>X. Qin, X. Yang, J. Wang, Q. Qin, J. Wang, X. Ye</i>	
SPATIAL SCALING TRANSFORMATION MODELING OF VEGETATION LEAF AREA INDEX RETRIEVED BY REMOTE SENSING IMAGE BASED ON FRACTAL	1547
<i>L. Wu, Q. Qin, X. Zheng, Y. Sun, Z. Gao</i>	
THIN ICE AREA EXTRACTION ALGORITHM USING AMSR2 DATA FOR THE SEA OF OKHOTSK.....	1553
<i>Y. Tokutsu, K. Cho</i>	
A NEW INTEGRATED SENSOR-COLLECTED INTELLIGENCE ARCHITECTURE BASED ON SATELLITE	1559
<i>W. Zhang, Q. Zhang, G. Cao, Y. Yao</i>	

WEBCON4 (1&II)

WEBCON 4 PROPOSAL	1560
<i>H.-M. Wu, K.-Z. Zhan, S.-C. Yu</i>	
BUILDING MODEL RETRIEVAL SYSTEM FOR AUTOMATIC CITY MODELING	1563
<i>Y.-C. Chen, J.-Y. Chen</i>	
WEB-BASED VIRTUAL TOUR GUIDE USING PANORAMAS OF CULTURAL HERITAGE SITE AT KINMEN	1571
<i>T.-C. Lin, T.-S. Wu</i>	
MYWATER - DECISION SUPPORT SYSTEM (DSS) FOR WATER YIELD ESTIMATION IN PENINSULAR MALAYSIA	1574
<i>M. Reba, M. Hashim, Amirul, F. Nadzri</i>	
PROPOSAL FOR WEBCON4	1577
<i>N. Katayama</i>	
FUTURE INFRASTRUCTURE INSPECTION USING GEOTAGGED PHOTO	1578
<i>K. Kataoka, T. Yamamoto</i>	
Author Index	

URBAN MORPHOLOGY ANALYSIS BY REMOTE SENSING AND GIS TECHNIQUE, CASE STUDY: GEORGETOWN, PENANG

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Abstract: This paper was analysed the potential of applications of satellite remote sensing to urban planning research in urban morphology. Urban morphology is the study of the form of human settlements and the process of their formation and transformation. It is an approach in designing urban form that considers both physical and spatial components of the urban structure. The study conducted in Georgetown, Penang purposely main to identify the evolution of urban morphology and the land use expansion. In addition, Penang is well known for its heritage character, especially in the city of Georgetown with more than 200 years of urban history. Four series of temporal satellite SPOT 5 J on year 2004, 2007, 2009 and 2014 have been used in detecting an expansion of land use development aided by ERDAS IMAGINE 2014. Three types of land uses have been classified namely built-up areas, un-built and water bodies show a good accuracy with achieved above 85%. The result shows the built-up area significantly increased due to the rapid development in urban areas. Simultaneously, this study provides an understanding and strengthening a relation between urban planning and remote sensing applications in creating sustainable and resilience of the city and future societies as well.

1. INTRODUCTION

Rapid development in urban settlement contributes to the changes of environmental, economic and social activities. This transition of the metropolitan area, city, town or village from the past to the present condition describe the process of urban growth which gives impacts to the form and structure of settlements. Therefore, urban morphology become as an essential key for the urban development to identify and determine the resilience of the whole urban system that will create urban dynamic as well. The understanding of urban growth and interpretation of urban morphology can be a key challenge to the rapid urbanization of the settlements.

Besides that, urban morphology analysis can help to identify the transformation of the urban form development and the evolutionary of urban form and structure (Cheng, 2011). Urban morphology plays fundamental role in the resilience of the urban system and enhances the urban growth of the specific settlement. It can represent as a tool to control the development activity and provide opportunities and constraints for city-building processes, such as land subdivision, infrastructure development, or building construction. The criteria in the evolutionary process of development at the particular city such as plots, blocks, street layout, buildings, urban material and open spaces are considered as part of the history. Therefore, this transformation affecting urban morphology includes economic, technological globalization, environmental and climate impact, demographic change and household preferences (Bentley and Butina 1990; Gillen, 2006).

The urban morphology analysis aided by using geographic information system (GIS) and remote sensing technique. These techniques can reveal the relationships of pattern, trend, form and structure of urban settlements. It will help to investigate the past and present patterns and trends of urban growth. Both techniques can provide a useful and direct measure of the physical form and morphology of urban land cover that is very useful in delineating the extent of individual urban settlements and in generating magnitude of size estimates for settlement systems (Batty and Longley, 1994). Moreover, the developments of these techniques have led to significant improvements in its capability for decision-making process in selected major areas.

2. INTERRELATION OF URBAN MORPHOLOGY, GIS AND REMOTE SENSING

Urban morphology is an approach in designing urban form that considers both physical and spatial components of the urban structure (Paul, 2008). In addition, urban morphology is the study of the city as a human habitat. It analyses a city's evolution from its formative years to current transformations which identifying and dissecting its various components. Therefore, buildings, gardens, parks, streets and monuments consider as main elements of morphology

analysis. However, these elements consider as organisms that constantly used and transformed through time. The urban morphology analysis could be a yardstick to understand and to design the sustainable urban form and spatial structure in order to produce dynamic urban settlements. As can be seen, the symbiotic and interrelation of the urban form towards economic, environment and social activities, will provide systematic interactions and resilience to the urban settlements.

Using GIS and remote sensing technique are the methods in analyzing the evolution of urban morphology. GIS is a computer-based information system used to digitally represent and analyse the geospatial data or geographic data. GIS technique enables to have a better understanding and evaluate data in many major areas such as environmental and natural resource management, facilities management, street network planning and engineering and information system. Therefore, GIS is most widely used technologies application that is used in the whole world.

Besides that, remote sensing also can detect the transformation of urban morphology when the transitions of land cover from one type to another or when the intensity of the land use or even the material composition changes. Moreover, urban morphology can change over time as the new urban fabric is added and as the existing fabric is internally modified. For example, new buildings replace old ones, plots are amalgamated or subdivided, street layout is modified and more. The changes of internal components are major concerns that represent the interrelation of physical evolution, such as economic, cultural and political dimensions that associated with the urban dynamics (Rashed et. al., 2005).

Urban morphology analysis requires multi-temporal data sets that covering the whole urban areas across a long period. This analysis can summarize the changes and trends of urban form and urban spatial structure. Therefore, morphology analysis can investigate the relationship between the land covers changes and population density from past and present year in order to identify the urban growth rate either decrease or increased, the population growth rate or the built up density.

Thus, this research is to identify the evolution and changes of urban morphology in urban settlements within particular years. Remote sensing and GIS is now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the analysis of earth's system function patterning and change at local, regional and even global scales. By using this method, the transition of urban settlements in terms of urban form and spatial structure can be analysed and it will help to forecast future development that suitable and create sustainable and resilience for urban growth.

3. STUDY AREA

The study is located in Georgetown, Penang. The history of Georgetown is located in the state of Penang. The state of Penang comprises of Penang Island and George Town is the heart of the metropolitan area which is the second largest urban conurbation in Malaysia. The city of Georgetown was established in 1786 by the British and it is the first British port town along the Straits of Malacca. Georgetown is listed as a UNESCO World Cultural Heritage Site in 2008 as "Historic Cities of the Straits of Malacca". It was the first British port town which has a unique architectural and cultural townscape without parallel anywhere in East and Southeast. The city has more than 200 years of urban history. Therefore, the urban morphology of Georgetown will be analysed to understand the trends and patterns of urban form and the expansion of urban growth.

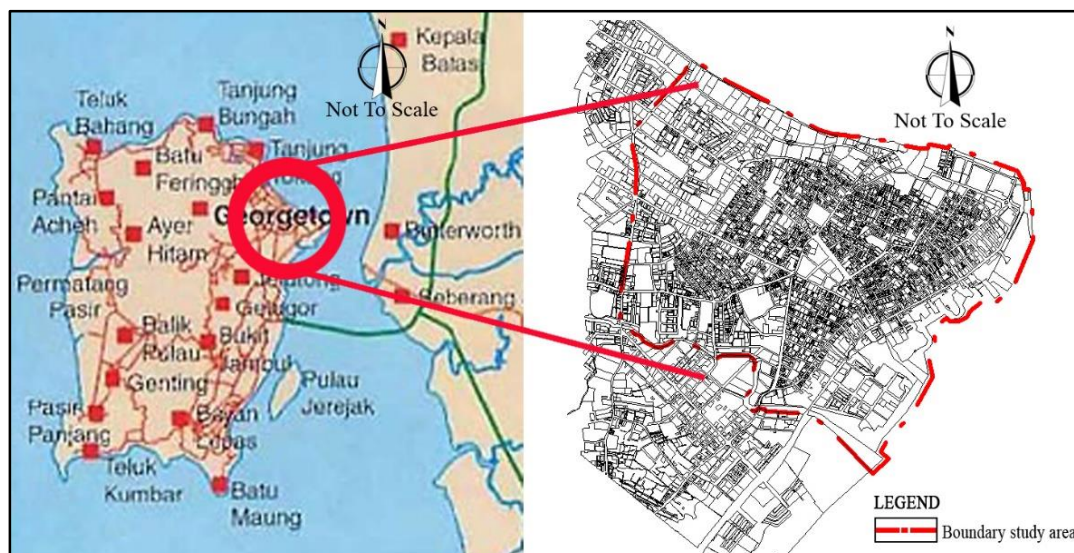


Figure 1:
Key Plan (left) and Location Plan (right) of the study area.

4. MATERIALS AND METHOD

4.1 Data and Ancillary Information

The data have been collected from primary and secondary data sources (Table 1). In this study, land use map of Georgetown, satellite images from Spot 5 J and Draft special area plan of Georgetown are used in this study. For Spot 5 J, there are four satellite images (nominally 2004, 2007, 2009, and 2014) are used in order to identify land-cover changes in the study area.

Table 1:
Materials and data used in this study.

Data Types	Year	Provider	Process	Output
Maps				
Land use map of Georgetown	2011	Town and Country Planning Department (TCPD)	Digitize, coordinates	Map of Georgetown 2011
Satellite Images				
Spot 5 J	2004,2007,2009,2014	Malaysian Remote Sensing Agency (MRSA)	Geometric correction, Enhancement, Classification	Land use and land cover map 2004,2007,2009 & 2014
Others				
Draft Special Area Plan Georgetown	2011	Town and Country Planning Department (TCPD) Pulau Pinang		
Google Map	2014	Website Google		

4.2 Methods

All the digital form of data is readily used in data processing in Digital Image Processing System and Geographic Information System. ERDAS IMAGINE 2014 are the main software that used to analyse the land cover changes, while MapInfo Professional 12.0 is the Geographic Information System used to generate various thematic layers consisting of Georgetown administrative boundaries, roads, land use, and boundary map in Georgetown map 2011.

The change detection technique is used in order to analyse the differences of the urban change by observing it at different times or interval years (2004, 2007, 2009 and 2014). Therefore, in this research, several satellite images from Spot 5 J satellite are used to detect the changes in the urban area. This technique involves the application of multi-temporal data sets to quantitatively analyse the temporal effects.

5. RESULTS AND DISCUSSION

In order to analyse the morphology and the expansion development in Georgetown City, four satellite images from the year 2004, 2007, 2009 and 2014 are classified using supervised classification aided by ERDAS IMAGINE 2014. The image classification is assigned with three different classes which build up area, unbuilt-up area and water bodies. The result of classification shows that three types of land use of the built-up, unbuilt-up area and water bodies are successfully classified. The assessment of the classification was carried out based on the classified image in each processing. Table 2 shows the accuracy assessment obtained from the classification process done to every each satellite imagery. An overall classification accuracy of over 85% has been achieved during image processing.

Table 2:
Accuracy Assessment for land use classification for the images

Satellite Images	Year	Accuracy (%)	Kappa Statistic
Spot 5 J	2004	95.00	0.9208
	2007	95.00	0.9200
	2009	93.68	0.8998
	2014	98.67	0.9776

Accuracy assessment is important in land use change detection technique which lead to determine the quality of the information based on the remotely sensed data. Moreover, this assessment reflects the degree of correctness of a map or classification.

5.1 Land Use Change Detection

After accuracy assessment successfully done, the change detection technique can be carried out to analyse the changes of land cover in Georgetown city. The result of the analysis due to the expansion of land use were highlighted through increases of percent in built-up and unbuilt-up area. It clearly shows that built-up area increases from 70.29% in 2004 to 78.45% in 2014. Meanwhile, for unbuilt-up area decrease of 15.3% (2004) to 8.2% (2014).

From the table, the average rate per year of built-up area increase to 11.8 acres per year with 0.7% within 11 year period. Due to the rapid urbanization occurred in Penang, most of the unbuilt up area became built up area to accommodate the demand capacity for future populations. It shows that Georgetown city was transformed to be one of the develop city in Malaysia.

Table 3
Comparison of area between land use class from year 2004 until year 2014

Types of Land Use	Year								Average Rate of Change (2004-2014)	
	2004		2007		2009		2014			
	Area (acre)	%	Area (acre)	%	Area (acre)	%	Area (acre)	%	Acre/yr	%/yr
Built-up Area	1119.0	70.3	1201.0	75.4	1219.0	76.6	1249.0	78.5	11.8	0.7
Unbuilt-up Area	243.4	15.3	166.0	10.4	153.0	9.6	130.8	8.2	10.2	0.6
Water Bodies	229.6	14.4	225.0	14.1	220.0	13.8	212.2	13.3	1.6	0.1

The result clearly shows that the urban development significantly increased. The expansion urban area mostly towards the Malacca Strait, where the Georgetown history as first British port cities. It shows that the town expands inwards and the series of reclamation with the extending towards Weld Quay as the new waterfront. Due to rapid changes faced by Georgetown, unbuilt-up area decreased and it lead to the built up area increased with the increasing intervention from high rise construction and new developments within the historic urban fabric. Hence, it gives some transformation and evolution in urban morphology of the city (Shuhana et. al., 2012).

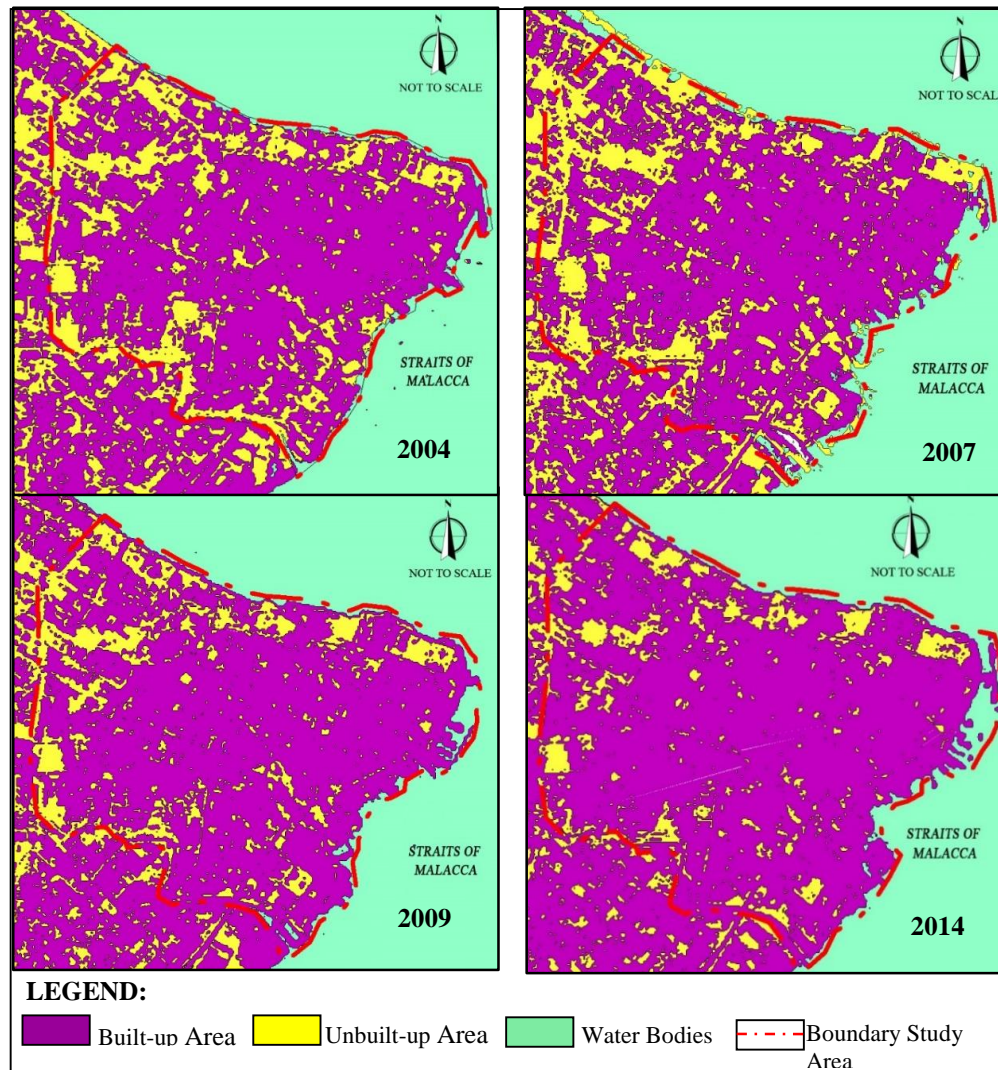


Figure 2:
Temporal land use classification in study area obtained from SPOT 5 J imageries

6. CONCLUSION

In this study, it shows that Georgetown city faced rapid development within 11 years from 2004 until 2014. Thus, it provides a basic understanding on how the city faced the evolution of development in terms of urban forms and urban spatial structure. With this knowledge, it can show how important of the city's history in designing and development to become one of the most resilient and sustainable city. In the recent years, the challenge facing most of the urban areas is how to accommodate future population and development growth in a sustainable manner. The Urban morphology study provides important knowledge to the planner in order to develop any area in a city or even for fringe belt. Lack of interest and awareness of history among the planner and others prevents developing the settlements into a systematic urban dynamic. Hence, the responsibility for the built environment is not taken seriously towards realization of sustainable urban development. Therefore, urban planners need information that will be enabled to respond to the expectations and needs of the urban growth. At this point, it can help to forecast future model of urban settlements.

Moreover, the urban morphology study can help in design control through policy. Due to deficiency in policy for design control, urban morphology study can be an important issue and can be taken as consideration in developing a method for expressing detailed design policies (Hall, 1997). Besides that, cultural diversity in Georgetown has a great contribution towards the morphology of the urban area. By having multi-culture, the government could play a role in implementing the cultural policies which can be as a benchmark in produce great urban transformation (Pereira & Nofre, 2011). Thus, the local and international tourist will understand the morphology of different culture that came to Georgetown with different background of ethnicity which established from ancient year. Hence, the guidelines and

policies should take seriously by all parties such as have local authorities, Federal and State governments, Department of Museums and Antiquity, heritage trusts and other professional bodies.

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